

## REMARKS

In view of the above amendments and the following remarks, reconsideration of the rejections contained in the Office Action of January 2, 2004 is respectfully requested.

In order to make various editorial corrections, the entire specification and abstract have been reviewed and revised, and the amendments to the specification and abstract have been incorporated into the attached substitute specification and abstract. For the Examiner's benefit, a marked-up copy of the specification indicating the changes made thereto is also enclosed. No new matter has been added by the revisions. Entry of the substitute specification is thus respectfully requested.

Claims 1-17 are presently pending in this application, although the Examiner has withdrawn claims 9-17 as being directed to a non-elected invention. The Examiner has also rejected claims 1-8 under 35 USC § 112, second paragraph, as being indefinite. In particular, the Examiner notes that claim 1 contains the units "mVvsSHE," and asserts that these units are not known and cannot be converted into known potential units.

In view of the above, non-elected claims 9-17 have now been cancelled. Furthermore, the Examiner's formal rejections of claims 1-8 are respectfully traversed. In particular, in contrast to the Examiner's position, it is submitted that one of ordinary skill in the art would clearly understand the meaning of the term "mVvsSHE," as will be explained below.

The Appendix submitted herewith includes printouts of publicly-accessible internet research sites. As explained in these printouts, the term "SHE" refers to the Standard Hydrogen Electrode, which is the universal reference standard for reporting relative half-cell potentials. In particular, the SHE is used for comparison purposes to provide meaning for a half-cell potential (i.e., to place the half-cell potential in a proper context). Thus, as is clear from the explanation provided in these printouts, the phrase "300 mVvsSHE" means 300 mV versus (i.e., as compared to) the Standard Hydrogen Electrode (SHE). Therefore, these printouts provide evidence that one of ordinary skill in the art would clearly understand that the term "mVvsSHE" refers to a potential, in volts, as compared to the potential of the Standard Hydrogen Electrode (SHE). However, in order to simply provide an *explicit* recitation of this understanding in an effort to avoid any misunderstanding, page 2 of the original specification has now been amended as indicated above, and it is submitted that this

modification does not include any new matter. Furthermore, in view of this explanation, the Examiner is respectfully requested to withdraw the rejections of claims 1-8 under 35 USC § 112.

On page 2 of the Office Action, the Examiner has indicated that claims 1-8 would be allowable if rewritten or amended to overcome the rejections under §112. As explained above, it is submitted that the Examiner's rejections of claims 1-8 under §112 have been overcome. Although several minor amendments have been made to the claims in order to place the claims in a preferred form, and new dependent claims 18-20 have been added, it is submitted that claims 1-8 and 18-20 are clearly patentable over the prior art of record as indicated by the Examiner on page 2 of the Office Action.

In view of the above amendments and remarks, it is submitted that the present application is now in condition for allowance. However, if the Examiner should have any comments or suggestions to help speed the prosecution of this application, the Examiner is requested to contact the Applicant's undersigned representative.

Respectfully submitted,

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# **APPENDIX**

Amendment Filed 3/30/04  
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## Standard Electrode Potentials

Standard potential differences are the actual cell potential differences measured in reversible cells under standard conditions. For solid or liquid compounds or elements, standard conditions are the pure compound or element; for gases they are 100 kPa pressure, and for solutes they are the ideal 1 molar (mol/liter) concentration.

Tables of standard electrode potentials can be obtained if any one electrode, operated under standard conditions, is designated as the standard electrode or standard reference electrode with which all other electrodes will be compared. This electrode is called the standard hydrogen electrode, abbreviated SHE. The potential difference across a reversible cell made up of any electrode and a Standard hydrogen electrode (SHE) is called the reversible potential of that electrode,  $E$ .

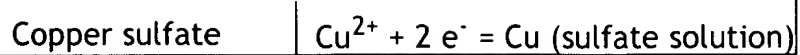
If this other electrode is also being operated under standard conditions of pressure and concentration, then the reversible potential difference across the cell is the standard electrode potential  $E^0$  of that electrode. In many practical potential measurements, the standard hydrogen electrode cannot be used because hydrogen reacts with other substances in the cell or because other substances in the cell react with the catalytic platinum electrode surface upon which the  $H^+/H_2$  potential is established.

It is often much more convenient to use alternative electrodes whose potentials are precisely known with respect to the SHE. Two of the electrodes most commonly used for this purpose are the Ag/AgCl electrode, //  $AgCl(s), Cl^-/Ag(c)$  at  $E^0 = +0.2224$  V vs. SHE, and the saturated calomel electrode (SCE) at 0.241 V vs. SHE. The effect of changing the reference electrode is to change the zero of a potential scale while leaving the relative positions of all of the potentials unchanged.

### Equilibrium reaction of the main reference electrodes used in corrosion

Name	Equilibrium reaction
<u>Hydrogen</u>	$2 H^+ + 2 e^- = H_2$
<u>Silver chloride</u>	$AgCl + e^- = Ag + Cl^-$
Calomel	$Hg_2Cl_2 + 2 e^- = 2 Hg + 2 Cl^-$
Mercurous sulfate	$Hg_2SO_4 + 2 e^- = 2 Hg + SO_4^{2-}$
Mercuric	$HgO + 2 e^- + 2 H^+ = Hg + H_2O$

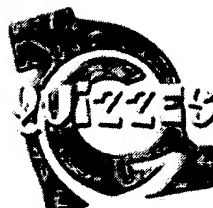
Copper sulfate



The potential corresponding to these half-reactions can be calculated from basic thermodynamic data by ...

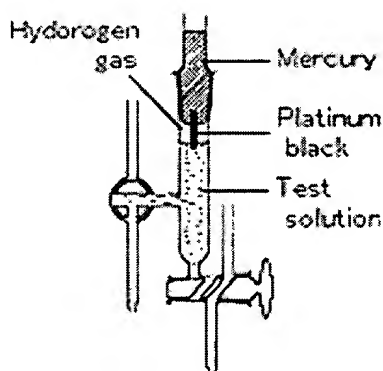
- first calculating the energy at a function of temperature for all chemical species involved
- then using Nernst equation to adjust for non standard activities or concentrations





## Standard Hydrogen Electrode (SHE)

The SHE is the universal reference for reporting relative half-cell potentials. It is a type of gas electrode and was widely used in early studies as a reference electrode, and as an indicator electrode for the determination of pH values. The SHE could be used as either an anode or cathode depending upon the nature of the half-cell it is used with. The SHE consists of a platinum electrode immersed in a solution with a hydrogen ion concentration of 1.00M. The platinum electrode is made of a small square of platinum foil which is platinized (known as platinum black). Hydrogen gas, at a pressure of 1 atmosphere, is bubbled around the platinum electrode. The platinum black serves as a large surface area for the reaction to take place, and the stream of hydrogen keeps the solution saturated at the electrode site with respect to the gas. It is interesting to note that even though the SHE is the universal reference standard, it exists only as a theoretical electrode which scientists use as the definition of an arbitrary reference electrode with a half-cell potential of 0.00 volts. (Because half-cell potentials cannot be measured, this is the perfect electrode to allow scientists to perform theoretical research calculations.) The reason this electrode cannot be manufactured is due to the fact that no solution can be prepared that yields a hydrogen ion activity of 1.00M.



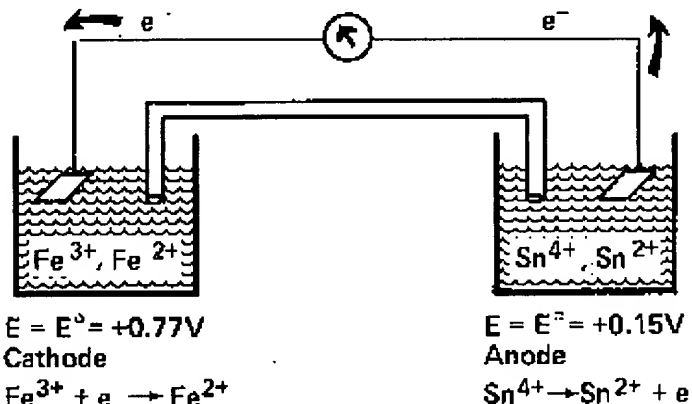
hydrogen electrode is made by adding platinum black to platinum wire or a platinum plate. It is immersed in the test solution and an electric charge is applied to the solution and platinum black with hydrogen gas. The hydrogen-electrode method is a standard among the various methods for measuring pH. The values derived using other methods become trustworthy only when they match those measured using hydrogen electrode method. However, this method is not appropriate for daily use because of the effort and expense involved, with the inconvenience of handling hydrogen gas and great influence of highly oxidizing or reducing substances in the test solution. (reference)

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## Electrochemical Potentials

The potential difference across an electrochemical cell,  $DE$ , is the potential difference (in volts) measured between two electronic conductors. In the external circuit connected to an electrochemical cell, the electrons will flow, as they normally do in electronic conductors, from the most negative point to the most positive point. This means that the electrons in the external circuit connected to an electrochemical cell will always flow from the most negative electrode to the least negative electrode. Since the potentials of electrodes can be either positive or negative, the electrons in the external circuit can also be said to flow from the least positive electrode to the most positive electrode.

Voltmeters or other devices used to measure the potential differences across electrical circuits or electrochemical cells measure potential differences, and so they cannot measure the actual potential of any electrode. Nevertheless, it is convenient to assign part of the cell potential to one electrode and part to the other. When this is done, that part of the cell potential assigned to each electrode has a physically real value which includes a physically real sign. **Both value and sign have physical significance.**



## Standard Electrode Potentials

Standard potential differences are the actual cell potential differences measured in reversible cells under standard conditions. Standard conditions for substances in electrochemical cells are the same as the standard conditions used elsewhere in chemistry. They have been, and will be, discussed in several different sections. For solid or liquid compounds or elements, standard conditions are the pure compound or element; for gases they are 100 kPa (1.0 bar) pressure; and for solutes they are the ideal dilute solution of 1.0 mol/litre concentration. Unless otherwise specified, standard conditions also refer to a total pressure of 100 kPa. Some other sources of chemical information, and many older chemistry textbooks, use an older standard condition for pressure, 1.0 atm, and as a consequence their standard potentials may differ slightly (less than 0.1 V) from those given in the tables of standard potentials used here.

A table of standard electrode potentials is more useful than a table of standard cell potential differences because it contains much more information in much less space. Tables of standard electrode potentials can be obtained if any one electrode, operated under standard conditions, is designated as the standard electrode or standard reference electrode with which all other electrodes will be compared. This standard reference electrode can then arbitrarily be assigned an electrode potential of zero, just as sea level is assigned the elevation of zero.

Chemists have universally agreed to select the electrode reaction of the simplest element, hydrogen, as the reaction and electrode against which all others will be compared. This electrode is called the **standard hydrogen electrode**, abbreviated S.H.E.. The physically measured potential difference across a reversible cell made up of any electrode and a standard hydrogen electrode--a hydrogen electrode which is being operated under standard conditions of pressure and concentration--is called the reversible potential of that electrode,  $E$ . If the electrode other than hydrogen is also being operated under standard conditions of pressure and concentration, then the reversible potential difference across the cell is the standard electrode potential or **standard potential**,  $E^0$  of the electrode other than hydrogen.

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Example. The reversible potential difference across a cell containing a hydrogen electrode and an oxygen electrode is 1.23 V, the oxygen electrode being the more positive. One could assign the potential of the hydrogen electrode as 0.0 V, in which case the potential of the oxygen electrode must be +1.23 V (this is the usual assignment). One could also assign the potential of the oxygen electrode as 0.0 V, in which case that of hydrogen must be -1.23 V, or assign the potential of oxygen as +1.00 V, in which case the potential of hydrogen must be -0.23 V (these are not the usual assignments).

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The potential difference across a cell in which one of two electrodes is a standard hydrogen electrode is by definition the electrode potential of the other electrode, since the potential of the standard hydrogen electrode is zero. If neither of the two electrodes is a standard hydrogen electrode, the potential difference across the cell is the difference of the two electrode potentials including their sign.

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Example. A Sn(IV)/Sn(II) electrode in a half-cell having a potential of -0.10 V is connected to the half-cell of a  $\text{Fe}^{3+}/\text{Fe}^{2+}$  electrode having a potential of +0.70 V. The potential difference across the cell is 0.80 V, the iron electrode being the more positive.

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Example. A  $\text{Cd}^{2+}/\text{Cd}$  electrode in a half-cell having a potential of -0.37 V is connected to the half-cell of a  $\text{Sn}^{2+}/\text{Sn}$  electrode having a potential of -0.15 V. The potential difference across the cell is 0.22 V, the tin electrode being the more positive.

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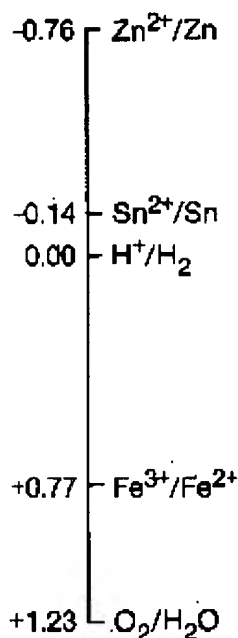
In many practical potential measurements, the standard hydrogen electrode cannot be used because hydrogen reacts with other substances in the cell or because other substances in the cell react with the catalytic platinum electrode surface upon which the  $\text{H}^+/\text{H}_2$  potential is established. Chemists then employ alternative electrodes whose potentials are precisely known with respect to the standard hydrogen electrode. Two of the electrodes most commonly used for this purpose are the AgCl/Ag electrode, //AgCl(s), Cl<sup>-</sup>/Ag(c) at  $E^0 = +0.2221$  V, and the saturated calomel electrode (SCE). The chloride concentration in the AgCl/Ag electrode is the standard concentration, 1.0 molar. The saturated calomel electrode is based on the  $\text{Hg}_2\text{Cl}_2(\text{s})/\text{Hg}(\text{l})$  couple. However, the saturated calomel electrode is not //Hg<sub>2</sub>Cl<sub>2</sub>(c), Cl<sup>-</sup>(aq, 1.0 molar)/Hg(l) but //Hg<sub>2</sub>Cl<sub>2</sub>(c), KCl(aq, sat.)/Hg(l). The solution is saturated not only with Hg<sub>2</sub>Cl<sub>2</sub> but also with KCl, and the saturation concentration of the highly soluble KCl is well above 1.0 molar. As a consequence the potential of the SCE reference electrode, +0.2412 V, differs significantly from the standard reduction potential of the  $\text{Hg}_2\text{Cl}_2(\text{c})/\text{Hg}(\text{l})$  couple, +0.2680 V.

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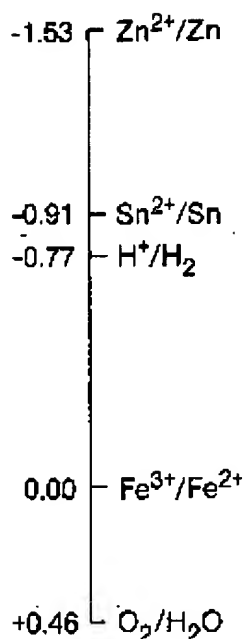
The effect of changing the reference electrode is to change the zero of a potential scale while leaving the relative positions of all of the potentials unchanged, as shown in the Figure below.

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HYDROGEN SCALE



IRON SCALE

Example. A cell containing a  $\text{Sn}^{4+}/\text{Sn}^{2+}$  electrode and a saturated calomel reference electrode has a measured potential difference of 0.1077 V, the saturated calomel electrode being positive. The potential of the  $\text{Sn}^{4+}/\text{Sn}^{2+}$  electrode on the standard hydrogen reference scale is calculated as follows.

The tin electrode is 0.1077 V negative of saturated calomel, which in turn is 0.2412 V positive with respect to standard hydrogen. Standard hydrogen is therefore 0.2412 V negative of saturated calomel. The potential difference between standard hydrogen and tin is  $0.2412 - 0.1077 = 0.1335$  V, hydrogen being the more negative. The potential of the tin electrode is thus +0.1335 V on the standard hydrogen reference scale. Since the tin electrode does not in this example have standard concentrations of one molar, its value differs from the standard potential of the  $\text{Sn}^{4+}/\text{Sn}^{2+}$  couple, +0.1539 V.

[NEXT: Electrode Potentials: Standard Potential Series]

[PREVIOUS: Electrode Structures and Notations]

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## ***standard hydrogen electrode***

The most fundamental reference electrode in electrochemistry. "By definition" its equilibrium potential is considered zero at any temperature, because this electrode was chosen as an arbitrary zero point for electrode potentials. A zero point is needed since the potential of a single electrode cannot be measured, only the difference of two electrode potentials is measurable. All electrode potentials are expressed on this "hydrogen scale." It is a hydrogen electrode with an electrolyte containing unit concentration of hydrogen ions and saturated with hydrogen gas at unit atmosphere pressure. This electrode can be somewhat inconvenient to use because of the need to supply hydrogen gas. Therefore, other reference electrodes (e.g., calomel or silver/silver chloride) are often used instead, but the measured electrode potentials can be converted to the "hydrogen scale." Abbreviated as "SHE." Also called "normal hydrogen electrode."

Strictly speaking, one must use unit activity rather than concentration of hydrogen ions and unit fugacity rather than unit pressure of hydrogen gas.